One-Pot Hydrogen Production and Carbon Valorization via Innovative Borate-boosted Bio-alcohol Conversion

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Hydrogen is widely recognized as a pivotal energy vector to achieve net-zero emissions by 2050, serving both as a versatile energy carrier and an industrial feedstock. However, current production methods are still largely based on fossil fuels, resulting in significant CO_2 emissions. The development of innovative and sustainable pathways for hydrogen production is therefore critical to achieving decarbonization goals.

In this context, our research group has developed and patented (WO 2023/105545 A1) an innovative process for hydrogen production from bio-alcohols and sodium metaborate, a by-product of sodium borohydride hydrolysis. The process operates in batch reactors in series at 300 °C, feeding bio-alcohol and water alternatively to sodium metaborate. This configuration enables both hydrogen production and carbon valorization from renewable feedstocks.

Using bioethanol, the process produces high-purity hydrogen (>95% v/v) at 30-45 bar, suitable for blending into natural gas pipelines or direct use in fuel cells. Simultaneously, the process allows the production of marketable chemicals in the liquid phase and a solid mainly consisting of oligoethylene $(-CH_2-CH_2-)n$, with potential applications as synthetic lubricant and viscosity modifier [1]. Employing crude glycerol, a cheap and widely available by-product, the selectivity in hydrogen reaches 55% v/v, generating a gas stream suitable for downstream upgrading, such as methanation for synthetic natural gas (SNG) production. Additionally, the in-situ produced hydrogen enables cascading reactions leading to valuable co-products, including 1,2-propanediol and thermally stable aromatic resins in the solid phase [2].

A key innovation of the process lies in the integration of sodium metaborate, traditionally regarded as a bottleneck in hydrogen storage loop due to its regeneration issues. Here, sodium metaborate plays a dual role as both alkaline stabilizer and reaction promoter, enabling one-pot bio-alcohol dehydrogenation and oligomerization. Moreover, the use of bio-alcohols as inherently CO_2-neutral reduces the carbon footprint associated with the hydrogen production chain.

This approach represents advancement in hydrogen production technologies by combining high-efficiency hydrogen generation and carbon valorization in a single pathway.

Keywords: *hydrogen, bio-alcohols, carbon valorisation, sodium metaborate*

References:

1 Di Nardo, A. ACS Omega. 2024, 9, 7, 7793-7805

2 Di Nardo, A. Engineering Journal 2024, 500, 156634